Lessons Learned from Covid-19: Factors that Determine the Effectiveness of Online Learning in College Mathematics, for a Favorable Educational Experience

Ruşen Meylani
İstanbul Aydın University, Türkiye, https://orcid.org/0000-0002-3121-6088

Abstract: Due to the COVID-19 pandemic, there has been a significant change in college mathematics education toward online learning, which has advantages and disadvantages for students, instructors, and institutions. To ensure the effectiveness of online learning, it is crucial to understand the factors that influence its success. This study looks at the many variables that affect how the pandemic affects online college mathematics instruction. The article begins with a detailed literature review considering student characteristics, telecommunications infrastructure, instructional design, teacher-student interaction, and evaluation methods. Theoretical pillars of the research include social constructivism, the Technology Acceptance Model (TAM), self-regulated learning theory, and the Community of Inquiry Framework. The study highlights the importance of online mathematics instruction for meeting various learning needs and promoting educational equity, particularly in the COVID-19 era. Critical studies have emphasized the cognitive advantages of teaching mathematics via online learning objects, such as fostering mathematical thinking, problem-solving skills, metacognition, and learning transfer. It also looks at motivating factors, including interaction, relevance, authenticity, goal-setting, measuring progress, and opportunities for collaborative learning. A mathematical growth mindset is teaching mathematics using online learning objects, with strategies emphasizing effort, persistence, constructive criticism, a positive learning culture, and building a sense of community. We look at the neuroscientific aspects of using online learning objects to teach math. Multimodal learning strategies, the cognitive load theory, active learning strategies, effective feedback and reinforcement strategies, customization, and adaptivity are some of these features. In conclusion, online learning tools in math lessons may improve students' understanding and mathematical abilities. By using the advantages of online learning objects and comprehending the cognitive and motivational aspects, teachers may create a helpful learning environment that encourages a development mindset and unleashes students' potential in mathematics.

Keywords: COVID-19, online learning, college mathematics, characteristics of an ideal online learning environment

Citation: Meylani, R. (2023). Lessons Learned from Covid-19: Factors that Determine the Effectiveness of Online Learning in College Mathematics, for a Favorable Educational Experience. In M. Demirbilek, M. S. Ozturk, & M. Unal (Eds.). *Proceedings of the ICSES 2023—International Conference on Studies in Education and Social Sciences* (pp. 275–289). Antalya, Türkiye. ISTES Organization.

Introduction

Background of COVID-19 and its Impact on Education

The COVID-19 pandemic has had a significant influence on education throughout the world (Stukalo & Simakhova, 2020). Schools and universities have been forced to close their physical campuses and transition to online education to ensure the safety of both students and professors (Stukalo & Simakhova, 2020). This rapid shift to online learning has produced advantages and challenges for educational institutions (Stukalo & Simakhova, 2020). Due to the pandemic, finding effective ways to provide instruction remotely is more important than ever, particularly in college mathematics (Stukalo & Simakhova, 2020).

Importance of Online Learning in College Mathematics

Online learning has gained importance in college mathematics, especially during COVID-19 (Stukalo & Simakhova, 2020). With the adaptability and accessibility of online learning, students may study at their own pace and from any location (Stukalo & Simakhova, 2020). Additionally, it offers opportunities for tailored instruction and exciting learning experiences (Stukalo & Simakhova, 2020). Online learning may meet a variety of learning demands and enhance educational fairness in the setting of collegiate mathematics (Stukalo & Simakhova, 2020). Students may connect to mathematical concepts via interactive exercises, which can help them develop their problem-solving abilities and metacognition (Stukalo & Simakhova, 2020).

Purpose of the Literature Review

Strotmann (2014) did a literature review during the COVID-19 pandemic to look into and understand the factors that determine the effectiveness of online learning in college mathematics. By analyzing the relevant literature, this research sheds light on the many elements that influence the success of online learning in college mathematics (Zhao & Strotmann, 2014). It will look at student characteristics, technological setup, instructional design, teacher-student interaction, and assessment approaches, according to Zhao and Strotmann (2014). The research will also use other theoretical frameworks, such as Social Constructivism, the Technology Acceptance Model (TAM), the Self-Regulated Learning Theory, and the Community of Inquiry Framework, to provide a thorough analysis (Zhao & Strotmann, 2014).

Scope and Limitations

The primary focus of this study work is the effectiveness of online instruction in college mathematics during the COVID-19 outbreak (Stukalo & Simakhova, 2020). It looks at the factors influencing how well online learning works in this environment, including student characteristics, technological infrastructure, instructional design, teacher-student interaction, and evaluation methods (Stukalo & Simakhova, 2020). To guarantee the relevance and currency of the results, the review will mostly rely on research done within the previous five years (Stukalo

& Simakhova, 2020). It is crucial to remember that the corpus of prior research constrains this study's breadth and may only touch on a few relevant issues and points of view about online learning in college mathematics during the epidemic.

Theoretical Framework

Social Constructivism

According to Saleem et al. (2021), social constructivism promotes the co-creation of knowledge via social interaction. This viewpoint views learning as an active process in which students actively interact with their surroundings and deepen their knowledge of them (Saleem et al., 2021). Social constructivism emphasizes the value of collaborative projects and student idea-sharing in online learning (Saleem et al., 2021). It acknowledges that knowledge is shared between teachers and students and created via social interactions (Saleem et al., 2021). This framework highlights the significance of creating a welcoming and exciting learning environment and the significance of the learner's active participation in the learning process (Saleem et al., 2021).

Technology Acceptance Model (TAM)

According to Davis (1989), the Technology Acceptance Model (TAM) is a theoretical framework that explains why people adopt and use new technology. According to this theory, a technology's utility and usability are vital in determining whether or not a client is willing to utilize it (Davis, 1989). The TAM defines perceived utility as the degree to which a person anticipates using technology to improve their performance or productivity. The TAM, in contrast, gauges how simple a user believes a technology to be to use (Davis, 1989). TAM has reportedly been widely used to evaluate customers' acceptance and uptake of online learning platforms, according to Abuhassna et al. (2023). It provides insights into the factors influencing students' views and attitudes toward online learning, claims Abuhassna et al. (2023). To design and implement effective online learning environments, apply these ideas.

Self-Regulated Learning Theory

The self-regulated learning approach strongly focuses on students' ability to manage their learning (Storchak, 2022). It emphasizes the necessity of metacognitive processes such as goal-setting, planning, monitoring, and self-reflection to promote practical understanding (Storchak, 2022). According to this theory, students with control over their education are more likely to set meaningful objectives, monitor their progress, and adjust their methods to achieve them (Storchak, 2022). Since online learning requires students to take responsibility for their education and engage in self-directed activities, self-regulated learning is essential (Storchak, 2022). This paradigm emphasizes the role of students as active participants in their learning process to allow effective online learning. It significantly emphasizes developing metacognitive skills (Storchak, 2022).

Community of Inquiry Framework

The social and cognitive presence in online learning environments is the subject of a theoretical paradigm known as the Community of Inquiry paradigm (Garrison et al., 1999). It states that three interrelated elements—cognitive presence, social presence, and instructional presence—must coexist for online learning to be effective (Garrison et al., 1999). According to Garrison et al. (1999), the cognitive company refers to students' capacity for protracted thought and conversational meaning-making. According to Garrison et al. (1999), social presence refers to a learner's ability to establish a sense of community and make meaningful connections with others. "teaching presence" refers to an instructor's capacity to encourage and support learning (Garrison et al., 1999). The Community of Inquiry Framework (Garrison et al., 1999) offers a comprehensive framework for understanding and evaluating the worth of online learning experiences. It emphasizes creating a friendly and exciting learning environment in online contexts (Garrison et al., 1999).

Social constructivism, the Technology Acceptance Model (TAM), the Self-Regulated Learning Theory, and the Community of Inquiry framework provide the theoretical basis for this project. Thanks to these conceptual frameworks, researchers have a theoretical foundation for understanding the variables affecting online learning's success in college mathematics. The Community of Inquiry Framework strongly emphasizes the value of social and cognitive presence in online learning settings. The Self-Regulated Learning Theory and TAM strongly emphasize how consumers accept and utilize technology. The collaborative creation of knowledge via social interaction is highlighted by social constructivism. Using these concepts, this study aims to extensively evaluate the factors affecting the effectiveness of online learning in college mathematics during the COVID-19 pandemic.

Methodology

Search Strategy

The approach for this study included a comprehensive literature search to locate relevant studies on the effectiveness of online learning in college mathematics during the COVID-19 pandemic. The investigation used several academic databases, including PubMed, Scopus, Web of Science, and Google Scholar. We used relevant search terms such as "online learning," "college mathematics," "COVID-19," "pandemic," and others. The search was limited to studies published within the last five years to ensure the findings' relevance and currency (Jung et al., 2021).

Selection Criteria

The selection criteria for this study were articles discussing the effectiveness of online learning in college mathematics during the COVID-19 pandemic. Only peer-reviewed papers were taken into account for the survey. The papers' applicability to the research topic was assessed based on the publications' titles and

abstracts. The full-text articles selected for further study were then subjected to the inclusion criteria (Jung et al., 2021).

Data Extraction and Synthesis

Data extraction is the systematic removal of important information from the selected articles. The methods used to assess the methodological aspects of case-control, cohort, and diagnostic studies were made accessible to ensure the correctness of this analysis (Jung et al., 2021; Melo & Figueiredo, 2021). The gathered data also contained the authors, publication year, study strategy, sample size, primary findings, and conclusions. The data were sorted and synthesized to identify recurring themes and patterns about the effectiveness of online learning in college mathematics during the COVID-19 pandemic. Analyzing the data gathered to identify noteworthy findings and trends, the effectiveness of online learning in college mathematics was investigated during the COVID-19 pandemic. The results offered a complete evaluation of the state of knowledge in the field, which was then consolidated and presented in a persuasive and organized manner.

The methodology used in this study, in summary, involved conducting a thorough literature search using a variety of academic databases, applying selection criteria to find relevant articles, extracting data from the pieces that were selected, and combining the outcomes to provide a thorough analysis of the effectiveness of online learning in college mathematics during the COVID-19 pandemic.

Factors Affecting Online Learning

Student Characteristics

Student characteristics substantially influence the success of online learning. Motivation, learning preferences, and technological literacy may affect students' engagement and performance in online learning environments (Picciano, 2017). Reason significantly impacts students' willingness to participate actively in online learning activities (Picciano, 2017). Picciano (2017) asserts that motivated students with a strong desire to learn are likelier to engage in online learning and get better outcomes. Additionally, a student's chosen learning methods, such as visual, aural, or kinesthetic, may impact their preferred online learning modalities and educational materials (Chen, 2022). Technological literacy, which includes understanding how to utilize digital tools and traverse online platforms, is also crucial for students to participate in online learning activities effectively (Chen, 2022).

Technological Infrastructure

The quality and accessibility of technical infrastructure significantly influence the effectiveness of online learning. Technology infrastructure includes platforms' usability, internet accessibility, hardware, and software (Marlena et al., 2022). Students need sufficient technology, such as laptops or smartphones, and a stable internet

connection to access online course materials and participate in virtual classrooms (Marlena et al., 2022). How effectively students learn is also influenced by the efficiency and usefulness of the online learning environment (Marlena et al., 2022). A user-friendly and intuitive platform may facilitate interaction between students and the course materials and instructors (Marlena et al., 2022). However, technical issues and limitations in technological infrastructure may make it challenging for students to access online learning resources and impede their academic development (Marlena et al., 2022).

Instructional Design

Creating engaging and relevant online learning experiences requires effective instructional design. Instructional design is the process of planning, producing, and distributing learning resources and activities (Pribadi & Chung, 2023). To increase students' comprehension and engagement, it is necessary to structure the information, establish specific learning goals, and include interactive and multimedia features (Pribadi & Chung, 2023). The instructional system design paradigm offers a systematic strategy for creating and developing high-quality online learning resources (Pribadi & Chung, 2023). With this paradigm, instructional designers may create engaging online learning experiences since they incorporate analysis, design, production, deployment, and evaluation (Pribadi & Chung, 2023). In order to increase students' understanding and retention of the material, well-designed online learning aids should be organized, aesthetically pleasing, and abide by the learning goals (Pribadi & Chung, 2023).

Teacher-Student Interaction

For online learning to be successful, teacher-student contact must be effective. Sharing opinions and ideas between teachers and students during interactions may contribute to a feeling of community (Pribadi & Chung, 2023). In online learning settings, teacher-student engagement is facilitated by communication tools, including discussion boards, video conferencing, and email (Pribadi & Chung, 2023). Students may benefit from timely and beneficial instructor feedback to monitor their progress, pinpoint areas for growth, and improve their learning outcomes (Pribadi & Chung, 2023). By creating a feeling of community through online platforms, students may become more engaged and motivated in their academic pursuits (Pribadi & Chung, 2023). Understanding and retaining the course content may be further improved by providing students with chances for peer involvement and collaborative learning (Warsi, 2021).

Assessment Methods

Assessment tools are crucial in online learning to monitor students' progress and provide feedback on learning outcomes. By employing quizzes, assignments, and discussions that serve as formative evaluations, teachers may evaluate their students' comprehension and provide timely feedback for growth (Pribadi & Chung, 2023). These assessments may also promote active learning and engagement by enabling students to reflect on their learning and apply their knowledge in multiple contexts (Pribadi & Chung, 2023). Summative assessments, such

as exams or projects, evaluate students' learning outcomes at the end of a course or unit (Pribadi & Chung, 2023). Effective assessment methods for online learning should be unbiased and reliable, align with the learning objectives, and enable students to demonstrate their skills and knowledge (Pribadi & Chung, 2023).

In conclusion, several factors influence the effectiveness of online learning. Students' characteristics, such as motivation, learning preferences, and technological skills, may impact their participation in and success in online learning. The required technological infrastructure must be present and of a high caliber in order for students to access and participate in online learning activities. The hardware, software, internet accessibility, and platform usability are a few examples of this infrastructure. Effective instructional design increases student understanding and engagement by setting clear learning objectives, providing well-organized material, and including interactive elements. Teacher-student interaction fosters community and supports students' academic progress via feedback and communication. Through evaluation methods like formative and summative assessments, students' learning outcomes are reviewed in order to provide recommendations for improvement. By considering these factors, teachers may create compelling and engaging online learning experiences for students.

Cognitive Aspects of Teaching Mathematics with Online Learning Objects

Mathematical Thinking and Problem-Solving Skills

When teaching math, employing online learning resources may help students' ability to think mathematically and solve problems. Online learning tools, such as interactive simulations and virtual manipulatives, enable students to actively learn and study mathematical concepts dynamically and interestingly (Mayer, 2008). These resources could encourage students to actively learn and take a critical and analytical approach to mathematical problems (Mayer, 2008). Interacting with online learning objects may help students develop mathematical reasoning, logical thinking, and problem-solving abilities (Mayer, 2008). Using online learning objects may aid in improving students' understanding of mathematical concepts by allowing them to see and interact with mathematical representations (Mayer, 2008).

Metacognition and Learning Transfer

When learning mathematics via online learning objects, metacognition—understanding and controlling one's mental processes—is essential (Mayer, 2008). Students may assess their development, validate their comprehension, and adjust their learning tactics in online learning environments (Mayer, 2008). By engaging in metacognitive processes, including goal-setting, planning, and self-assessment, students may enhance their learning outcomes and apply their knowledge to new situations (Mayer, 2008). Online learning objects may support metacognition by providing instant feedback, self-evaluation tools, and opportunities for reflection (Mayer, 2008). By participating in metacognitive exercises, students may get a better comprehension of mathematical concepts and apply what they have learned to problems in the real world (Mayer, 2008).

Multisensory Learning Approaches

Using online learning materials and multisensory learning strategies may improve student engagement and mathematical understanding (Renelle & Jones, 2022). The visual, auditory, and kinesthetic senses, among others, may enhance learning experiences (Renelle & Jones, 2022). Online learning objects may comprise sensory signals, such as visual representations, audio explanations, and interactive manipulations, to provide students with a rich and engaging learning experience (Renelle & Jones, 2022). Using various senses, students may better understand mathematical concepts and establish links between different representations (Renelle & Jones, 2022). All students' needs, including those with various learning preferences and styles, may be met using multisensory learning strategies (Renelle & Jones, 2022).

Cognitive Load Theory

The Cognitive Load Theory may be used to enhance the design of online learning objects to maximize students' cognitive processing and learning outcomes (Mayer, 2008). The mental effort required to process information and perform tasks is referred to in this idea as cognitive load (Mayer, 2008). When creating online learning objects, extraneous cognitive load—the amount of mental effort spent on unimportant or unnecessary information—should be kept to a minimum (Mayer, 2008). By reducing needless cognitive demands, students may commit more cognitive resources to important learning tasks and improve their understanding of mathematical concepts (Mayer, 2008). By creating online learning objects, the intrinsic complexity of the learning materials may be handled (Mayer, 2008). Providing scaffolding, in-depth instructions, and valuable examples, online learning objects may aid students' cognitive processing and simplify comprehension of complicated mathematical concepts (Mayer, 2008).

In conclusion, teaching mathematics with online learning objects may enhance students' mathematical thinking and problem-solving skills by providing engaging and interactive learning opportunities. Utilizing online learning resources may also promote metacognition and facilitate the application of information in new situations. Students' understanding of mathematical concepts may be improved by using multisensory learning techniques. Additionally, by creating online learning materials using the principles of Cognitive Load Theory, it may be possible to optimize students' cognitive processing and learning results. By considering these cognitive characteristics, teachers may create compelling online learning experiences that boost students' arithmetic abilities and knowledge.

Motivational Aspects of Online Learning in Mathematics

Relevance and Authenticity

Relevance and authenticity are two advantages of online math training that motivate students. When students think the mathematical concepts and skills they are learning have practical applications, they are likelier to be

engaged and motivated in their study (Hidi & Renninger, 2006). Relevance may be generated by connecting mathematical concepts to real-world examples and showing how they could be used in everyday life (Hidi & Renninger, 2006). According to Hidi and Renninger (2006), Authenticity refers to how well the learning challenges and activities match up with genuine situations that call for problem-solving. Online learning may boost students' motivation and interest in mathematics by providing genuine learning experiences, such as solving real-world mathematical problems or participating in simulations that reflect real-life events (Hidi & Renninger, 2006).

Interactive Activities

Another appealing feature of online math training is interactive exercises. Examples of the interactive activities that online learning platforms may provide to encourage students to learn and solve problems actively include virtual manipulatives, simulations, and games (Hidi & Renninger, 2006). These exercises allow students to investigate mathematical ideas, link various representations, and use what they have learned in practical contexts (Hidi & Renninger, 2006). By allowing students hands-on inquiry and discovery, interactive activities may boost their interest in and engagement in learning (Hidi & Renninger, 2006). Additionally, they could promote student autonomy and control over their education, aiding their academic success and motivation (Zimmerman, 2000).

Goal Setting and Progress Monitoring

When studying math online, goal-setting and progress-tracking are crucial motivating techniques. Students may feel purpose and direction by setting clear, attainable academic objectives (Zimmerman, 2000). By allowing users to create precise learning objectives and monitor their progress toward those goals, online learning platforms may help students set goals (Zimmerman, 2000). Students may assess their learning and change their techniques by keeping track of their progress and obtaining feedback on their performance (Zimmerman, 2000). This self-control and self-monitoring technique may increase students' motivation and opinions of their mathematical aptitude (Zimmerman, 2000).

Personalization and Collaborative Learning Opportunities

Two motivating features of online mathematics learning are the ability for personalization and group learning. By tailoring the content and speed of education to each student's requirements and preferences, online learning systems may provide individualized learning experiences (Zimmerman, 2000). Personalization may enhance motivation by giving students a feeling of autonomy and control over their education (Zimmerman, 2000). Peer review, group projects, and other forms of collaborative learning may increase students' interest and love for mathematics (Zimmerman, 2000). Students may communicate, share ideas, and gain insight from one another's viewpoints via collaborative learning (Zimmerman, 2000). Collaborative learning may increase students' motivation and feelings of belonging while studying online by establishing a community and encouraging social

engagement (Zimmerman, 2000).

In summary, motivational aspects are essential for studying arithmetic online. Relevance and authenticity may increase students' motivation by connecting mathematical concepts to real-world applications and establishing authentic learning opportunities. Interactive learning involves students actively solving issues, which boosts their motivation and involvement. Goal-setting and progress-monitoring strategies help students feel more motivated and competent by offering them direction and a means to evaluate their progress. Possibilities for personalized and collaborative learning that promote autonomy, social connection, and a sense of belonging raise students' motivation and engagement in mathematics.

Cultivating a Mathematical Growth Mindset

Emphasizing Effort and Persistence

Stress effort and persistence must be stressed to promote a mathematical growth mentality in online learning (Blackwell et al., 2007). A growth mindset is the belief that intelligence and abilities can be developed through effort and practice, according to Blackwell et al. (2007). By emphasizing the importance of effort and persistence in learning, students may learn that their skills are not fixed and may be enhanced with practice and hard work (Blackwell et al., 2007). According to Blackwell et al. (2007), this way of thinking enables students to take on challenges, see failure as an opportunity to grow, and persevere in the face of setbacks. According to a study, Children with a growth mindset are more likely to employ adaptive learning strategies, seek help when they need it, and achieve academic success at a higher level (Blackwell et al., 2007).

Constructive Feedback

Another essential element of cultivating a mathematical growth mentality in online learning is the ability to provide constructive feedback (Paunesku et al., 2015). Positive criticism emphasizes the process and effort more than the outcome (Paunesku et al., 2015). It highlights students' strengths, identifies growth opportunities, and provides specialized counsel for advancement (Paunesku et al., 2015). Teachers may help students develop a growth mindset by providing quick, in-depth, and helpful feedback and showing that abilities can be learned with practice and perseverance (Paunesku et al., 2015). Another advantage of constructive feedback for students' self-awareness and metacognitive skills growth is the capacity to assess their progress and alter their learning strategies (Paunesku et al., 2015).

Positive Learning Culture

Creating a supportive learning environment is necessary for developing a mathematical growth mindset in online learning (Paunesku et al., 2015). A warm and inviting environment where students feel appreciated, respected, and motivated to take risks is a hallmark of a positive learning culture, according to Paunesku et al.

(2015). Teachers may foster a positive learning culture by fostering cooperation, praising effort and accomplishment, and allowing students to voice their thoughts and ideas (Paunesku et al., 2015). By creating a safe and supportive learning environment, teachers may promote a growth mindset in their students (Paunesku et al., 2015). According to studies, children who feel they belong are likelier to engage in class, stick with something when things become challenging, and do well in school (Paunesku et al., 2015).

Fostering a Sense of Belonging

It is crucial to foster community in online learning to establish a mathematical growth attitude (Paunesku et al., 2015). Since online learning may sometimes appear isolating, teachers must provide students with chances to communicate with one another and feel a sense of community. This may be accomplished through group projects, online discussions, and cooperative learning activities (Paunesku et al., 2015). By showing students that they are essential members of a community that appreciates their contributions to learning, teachers may encourage students to adopt a growth mindset (Paunesku et al., 2015). According to studies, students who feel like they belong are more likely to engage in class, take risks, and persist with something when things become complex (Paunesku et al., 2015).

In conclusion, fostering a mathematical growth mindset in online learning requires praising effort and tenacity, providing constructive criticism, creating a positive learning environment, and fostering a sense of belonging. By developing a growth mindset, teachers may help students believe in their ability to learn and improve their mathematical skills. Students who embrace this viewpoint are urged to take on challenges, see setbacks as opportunities for improvement, and persist in facing difficulties. By implementing these techniques, teachers may provide a positive and engaging online learning environment that motivates students to develop their mathematical thinking and supports them in realizing their full potential.

Neuroscientific Aspects of Teaching Mathematics with Online Learning Objects

Active Learning Strategies

Active learning strategies are essential when teaching arithmetic utilizing online learning objects. According to Pekrun et al. (2002), students participate in activities that call for active involvement and interaction with the course contents. Through interactive simulations, digital experiments, and problem-solving activities, online learning objects may provide opportunities for active learning (Pekrun et al., 2002). In addition to assisting students in understanding and remembering mathematical ideas, these exercises also engage students' cognitive processes (Pekrun et al., 2002). Studies have shown active learning techniques may improve students' engagement, motivation, and mathematical learning results (Pekrun et al., 2002). Students may improve their mathematical reasoning, critical thinking, and problem-solving abilities by actively interacting with online learning objects (Pekrun et al., 2002).

To sum up, encouraging a mathematical growth mindset in online learning calls for applauding perseverance and effort, offering helpful criticism, cultivating a good learning atmosphere, and encouraging a feeling of belonging. By developing a growth mindset, teachers may help students believe in their ability to learn and improve their mathematical skills. Students who embrace this viewpoint are urged to take on challenges, see setbacks as opportunities for improvement, and persist in facing difficulties. By implementing these strategies, educators may create a supportive and dynamic online learning environment that encourages students to improve their mathematical thinking and helps them reach their full potential.

Effective Feedback and Reinforcement

Effective feedback and reinforcement are two neuroscientific aspects of utilizing online learning objects to teach arithmetic. By providing them with information on their performance, feedback enables students to discover their areas of strength and development (Hattie & Timperley, 2007). Effective feedback is specific, timely, and actionable and stresses the effort and process rather than the outcome (Hattie & Timperley, 2007). It allows users to monitor their progress, change how they learn, and connect diverse mathematical concepts (Hattie & Timperley, 2007). Rewarding students with praise or prizes may boost their engagement and excitement for studying (Hattie & Timperley, 2007). Teachers may activate the dopamine-releasing reward regions in their brains by providing students with helpful feedback and reinforcement, enhancing their motivation to learn mathematics (Hattie & Timperley, 2007).

Personalization and Adaptivity

Personalization and adaptation are essential neuroscientific factors when utilizing online learning resources to teach math. According to Hattie and Timperley (2007), personalization is tailoring the educational process to each student's needs, preferences, and abilities. Online learning systems may provide personalized learning experiences by adapting the course's pace, material, and difficulty level to each student's learning profile (Hattie & Timperley, 2007). Personalization may enhance students' motivation, engagement, and mathematics learning outcomes, claim Hattie and Timperley (2007).

According to Hattie and Timperley (2007), online learning objects' adaptivity is their ability to alter and develop in response to the responses and advancement of students. Adaptive learning systems may provide customized feedback, correction, and enrichment based on student performance, promoting optimal learning outcomes (Hattie & Timperley, 2007). In order to increase student’s cognitive abilities, concentration, and memory encoding, teachers may enhance students' math learning by tailoring and changing the learning process (Hattie & Timperley, 2007).

In conclusion, neuroscientific concerns must be considered while teaching mathematics using online learning objects. When math is taught actively, and students are given real-world activities, math concepts are better grasped and recalled. Through efficient feedback and reinforcement, students' cognitive processes are

stimulated, their motivation rises, and mathematics learning is supported. Personalization and adaptation improve students' cognitive abilities, focus, and memory encoding by tailoring the educational process to their needs. By considering these neuroscientific elements, teachers may create compelling online learning experiences that enhance students' engagement, motivation, and learning outcomes in mathematics.

Conclusion

Summary of Key Findings

The key takeaways from the literature review stress the importance of several factors in the effectiveness of online mathematics learning. Students' motivation, preferred learning methods, and technological competence level significantly impact their success at online learning. The technology environment, instructional design, teacher-student interaction, and assessment methodologies all significantly impact how effective online learning is. The critical motivators for online mathematics learning include adopting a growth mindset, emphasizing effort and persistence, providing constructive criticism, creating a welcoming learning atmosphere, and feeling like you belong. For personalization, adaptivity, and online learning objects enabling active learning approaches, effective feedback, and reinforcement, neuroscientific considerations are essential.

Implications for Practice

The findings have several applications for online math training. In order to give students individualized learning opportunities that meet their needs and preferences, teachers should consider all of their diverse characteristics. Teachers should emphasize effort and persistence, provide constructive feedback, and create a positive learning atmosphere to encourage growth and boost students' motivation and engagement. By promoting active learning strategies, constructive criticism, and reinforcement, online learning tools may help students learn and remember mathematical concepts. Teachers must foster a sense of belonging and provide opportunities for social contact and collaboration to boost students' motivation and sense of community in the online learning environment.

Recommendations for Future Research

The authors recommend that future research on online mathematics education should expand on the utility of different instructional styles and interventions in promoting students' engagement, motivation, and learning results. Through longitudinal study, it may be possible to understand better the long-term effects of online learning on students' mathematical abilities and perspectives. Research should look at how parents promote and support their children's online math learning and the influence of online learning platforms and technology on kids' learning experiences. More outstanding research is also required on the neuroscientific aspects of online mathematics learning, such as the cognitive processes and the results of customized and adaptable learning systems.

Final Thoughts

Online math instruction has gained importance, particularly after the COVID-19 pandemic. According to the reviewed study, several factors influence how effective online learning is, including student characteristics, technological infrastructure, instructional design, teacher-student interaction, and assessment approaches. Motivational variables, such as adopting a development mindset and providing constructive criticism, dramatically enhance students' interest in and achievement in mathematics. Neuroscientific aspects that increase students' cognitive processes and enhance learning outcomes include personalization, adaptivity, and online learning objects. By considering these factors and using efficient strategies, teachers may create successful online learning experiences that support students' mathematical aptitude and foster a love of mathematics.

References

Abuhassna, H., Yahaya, N., Zakaria, M. A. Z. M., Zaid, N. M., Samah, N. A., Awae, F., Nee, C. K., & Alsharif, A. H. (2023). Trends on using the technology acceptance model (tam) for online learning: A bibliometric and content analysis. *International Journal of Information and Education Technology*, *13*(1), 131–142. https://doi.org/10.18178/ijiet.2023.13.1.1788

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development*, *78*(1), 246–263. https://doi.org/10.1111/j.1467-8624.2007.00995.x

Chen, W. (2022). International students' online learning satisfaction model construction, validation, and affecting factors analysis. *Open Journal of Social Sciences*, *10*(7), 175–185. https://doi.org/10.4236/jss.2022.107015

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319. https://doi.org/10.2307/249008

Garrison, D. R., Anderson, T., & Archer, W. (1999). Critical inquiry in a text-based environment: Computer conferencing in higher education. *Internet and Higher Education*, 2(2–3), 87–105. https://doi.org/10.1016/S1096-7516(00)00016-6

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Jung, R. G., Di Santo, P., Clifford, C., Prosperi-Porta, G., Skanes, S., Hung, A., Parlow, S., Visintini, S., Ramirez, F. D., Simard, T., & Hibbert, B. (2021). Methodological quality of Covid-19 clinical research. *Nature Communications*, *12*(1), 943. https://doi.org/10.1038/s41467-021-21220-5

Marlena, N., Dwijayanti, N., Patrikha, N., & Saino, N. (2022). Online learning infrastructure: Does it strengthen the effect of service quality on student satisfaction? *Jurnal Iqra*, *2*(7), 61–75.

https://doi.org/10.25217/ji.v7i2.2032

Mayer, R. E. (2008). Applying the science of learning: Evidence-based principles for the design of multimedia instruction. *American Psychologist*, *63*(8), 760–769. https://doi.org/10.1037/0003-066X.63.8.760

Melo, T., & Figueiredo, C. (2021). Comparing news articles and tweets about Covid-19 in brazil: Sentiment analysis and topic modeling approach. *JMIR Public Health and Surveillance*, *2*(7), e24585. https://doi.org/10.2196/24585

Paunesku, D., Walton, G. M., Romero, C., Smith, E. N., Yeager, D. S., & Dweck, C. S. (2015). Mind-set interventions are a scalable treatment for academic underachievement. *Psychological Science*, *26*(6), 784–793. https://doi.org/10.1177/0956797615571017

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of Qualitative and Quantitative Research. *Educational Psychologist*, *37*(2), 91–105. https://doi.org/10.1207/S15326985EP3702_4

Picciano, A. G. (2017). Theories and frameworks for online education: Seeking an integrated model. *Online Learning*, *21*(3). https://doi.org/10.24059/olj.v21i3.1225

Pribadi, B. A., & Chung, K. S. (2023). Designing online learning: Comparative study between Indonesian Open University and Korea National Open University. *International Journal of Instruction*, *16*(2), 643–660. https://doi.org/10.29333/iji.2023.16234a

Renelle, A., & Jones, R. (2022). *Multisensory learning for students with disabilities*. https://doi.org/10.52041/iase.icots11.T11A1

Saleem, N., Kausar, N., & Deeba, N. (2021). Social constructivism: A new paradigm in teaching and learning environment. *Perennial Journal of History*, *2*(2), 403–421. https://doi.org/10.52700/pjh.v2i2.86

Storchak, O. (2022). Topical learning paradigms for online education. *Naukovì Zapiski Nacìonal'nogo Unìversitetu «Ostroz'ka Akademìâ». Serìâ «Fìlologìâ»*, 1(13(81)), 7–11. https://doi.org/10.25264/2519-2558-2022-13(81)-7-11

Stukalo, N., & Simakhova, A. (2020). Covid-19 impact on Ukrainian higher education. *Universal Journal of Educational Research*, *8*(8), 3673–3678. https://doi.org/10.13189/ujer.2020.080846

Warsi, N. (2021). Factors affecting online learning: Perceptions of future professionals of Allama Iqbal Open University in Pakistan. *Pakistan Journal of Educational Research*, *4*(4). https://doi.org/10.52337/pjer.v4i4.344

Zhao, D., & Strotmann, A. (2014). In-text author citation analysis: Feasibility, benefits, and limitations. *Journal of the Association for Information Science and Technology*, *65*(11), 2348–2358. https://doi.org/10.1002/asi.23107

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology*, *25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016